# DEVELOPMENT OF THE SEMI-AUTOMATIC

# TWO-WAY RADIO STATION AS-3

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Progress Report No. 8

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Progress Report #8 [redacted] 50X1

Radio Station AS-3

November 1, 1957 EA-122-1

## GENERAL

### REPORTING PERIOD

This report covers the work accomplished by [redacted] 50X1
[redacted] on the development of the AS-3 50X1
Semi-automatic Two-way Radio Station during the period 1 September to 1 November, 1957.

### PERSONNEL ASSIGNED

Personnel assigned to this project on a full-time basis are:

[redacted] 50X1

[redacted] 50X1

### CONFERENCES

One conference was held during this report period; on 17 September at [redacted] A conference report 50X1
is attached.

This conference established the AT-3 power supply output as one for use with the transistorized receiver. It also re-established the battery charge function of the AP/AC-3 Power Supply.

## TECHNICAL DISCUSSION

Within three weeks all breadboards of the AS-3 system for which [redacted] is responsible will have been completed in such a 50X1
form that testing and evaluation can begin. The test program will follow the following schedule: The three subassemblies making up the Transmitter (AT-3) will be tested individually for electrical and mechanical performance. After they qualify, individually, they will be assembled as a (breadboard) AT-3 and unit tested mechanically and electrically. The Coder, AC Power Supply, Battery, and Charger will each be unit tested electrically and mechanically. If their unit performance is satisfactory, system testing will proceed.

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Unit tests will also be made on the Printer and Receiver if available. Then system testing will include these units.

The breadboard DC Power Supply Subassembly was finished early enough so that a complete set of electrical performance data on it could be taken. Therefore, the balance of this report is devoted to it. The status of all other subassemblies and units may be summarized as complete or nearly so, with testing in progress.

## DC POWER SUPPLY SUBASSEMBLY (BREADBOARD)

### Summary:

One of the major developments required on the AS-3 project has been the design of a compact, reliable, and efficient power supply to convert the battery voltage to the various bias and high voltages used in the transmitter.

Conventional designs based on vibrators would have produced a unit several times the size and weight of the AS-3 supply, and with relatively poor dependability. The completely transistorized AS-3 supply has successfully met each of its design goals to date.

In the AS-3 supply, the direct current input is applied to two high-power transistors connected in a self-excited multivibrator switching circuit. The transistors furnish reversing polarity, square-wave pulses to the primary of a specially designed toroidal transformer. The secondary of the transformer has a square-wave AC voltage output, whose magnitude is established by proper choice of the transformer turns ratio. The transformer secondary current is rectified and filtered to provide a DC output at the desired voltage.

### Circuit Design:

Refer to the AT-3 DC Power Supply Subassembly schematic, Figure 8-1. The regenerative action of feedback to the power transistors quickly drives one of the transistors to saturation. The other transistor is effectively cut off. The saturated transistor acts like a switch. It applies full supply voltage across one half of the primary winding. From Lenz's law ($e = -N\frac{d\phi}{dt}$) it can be seen that flux will increase linearly with time, in the core of the toroidal transformer. This flux may not increase without bounds because saturation flux density is reached after a period of time and flux may no longer increase. This is particularly true if a "square-loop" hysteresis characteristic core material is used. Saturation in the core material occurs abruptly and the rate of change of flux in the core must decrease virtually to zero.

When the rate of change of flux decreases, the feedback voltage to the transistor drops and takes the transistor out of saturation. The transistor can not sustain load current or core magnetizing current when it comes out of saturation. The flux in the core, therefore, begins to decrease. This reverses the sign of $\frac{d\phi}{dt}$ and a feedback voltage of the proper polarity to saturate the previously cut off transistor is developed. Regenerative action again takes place and this transistor is quickly driven to saturation. The second half of the primary goes through the same cycle as the first. Multivibrator action results and linearly increasing and decreasing flux is produced in the core. The secondary winding linking this flux has a square wave output of voltage as a result. If an operating frequency is chosen and the input voltage and desired output voltages are known, it is a simple matter to determine the number of primary turns and the primary to secondary turns ratio necessary in the toroidal transformers.

The number of primary turns on each half of the primary may be shown to be:

$$N = \frac{E \times 10^8}{4 \times A \times f \times B_{max}}$$

where: E = supply voltage

A = area of core in $cm^2$

f = frequency of oscillation in cps

Bmax = saturation flux density of core material

The frequency of oscillation of the power multivibrator is a function of the input voltage and the design of the toroidal transformer. A free choice of operating frequency may be made within certain limitations. It is desirable to choose as high a frequency as possible. The filter necessary to smooth the rectified DC output may be made very small since the effectiveness of a given filter is increased by a high operating frequency. The size of the toroidal transformer is also small for a high operating frequency. It is primarily as a result of the high frequency of oscillation of the power multivibrator that the size and weight advantages accrue.

The frequency of oscillation is limited quite loosely by the hysteresis losses in the toroidal transformer and by the "cut off frequency" of the power transistors. It is found in practice that an oscillating frequency of 1000 to 2000 cycles per second yields most efficient results.

If the secondary winding had perfect square wave output, it would be a simple matter to invert the negative half of the cycle with a full wave bridge rectifier and DC output could be obtained without need for filtering. However, this would require instantaneous transition of the transistors from a saturated state to a cut off state. In practice the transition requires approximately 3 to 5 microseconds.

The rectified secondary voltage has 3 to 5 microsecond gaps which must be filled by the output smoothing filter. A comparatively simple and small filter is required which again results in great savings in size and weight.

Electrical Test Results:

The DC Power Supply Subassembly is deemed to have satisfied the electrical performance requirements as a result of the data presented herewith:

Figure 8-1 is the schematic of the DC supply. The transformer is a special ARC design actually handling over 100 watts under full load in a volume of only 35 cubic inches.

Figure 8-2 is a photograph of the supply.

Figure 8-3 shows the test configurations used in measuring load, ripple, and noise characteristics of the supply.

Figure 8-4 is the output voltage vs. current characteristics of the supply at various input voltages and at temperatures of -40°C, +25°C, and +50°C.

Figure 8-5 is a graph of input current vs. load.

Figure 8-6 gives the efficiency of the supply at various input voltages and at temperatures of -40°C, +25°C, and +50°C.

Figure 8-7 shows the ripple content of the supply under laboratory ambient conditions.

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Figure 8-8 is the radiated noise characteristic of the supply as measured according to the procedures of MIL-I-6181B. The plot as shown is extrapolated for noise voltages below 1.0 microvolt as the noise measuring equipment will not give meaningful data below that level. This data is not conclusive of unit performance in that packaging of the subassembly within the unit frame will reduce this figure.

Figure 8-9 defines the conducted noise of the supply, again as measured according to MIL-I-6181B. When the system tests are performed, it is anticipated that conducted noise will be reduced even further, as the lead-conducted noise will either be terminated in the low output impedance of the AC supply, or in the battery.

Prepared by:

RWH/RFP:sk
Attach: Confer. Rept. dtd. 9/25/57.

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AT-3
DC Power Supply Subassembly
Schematic Diagram

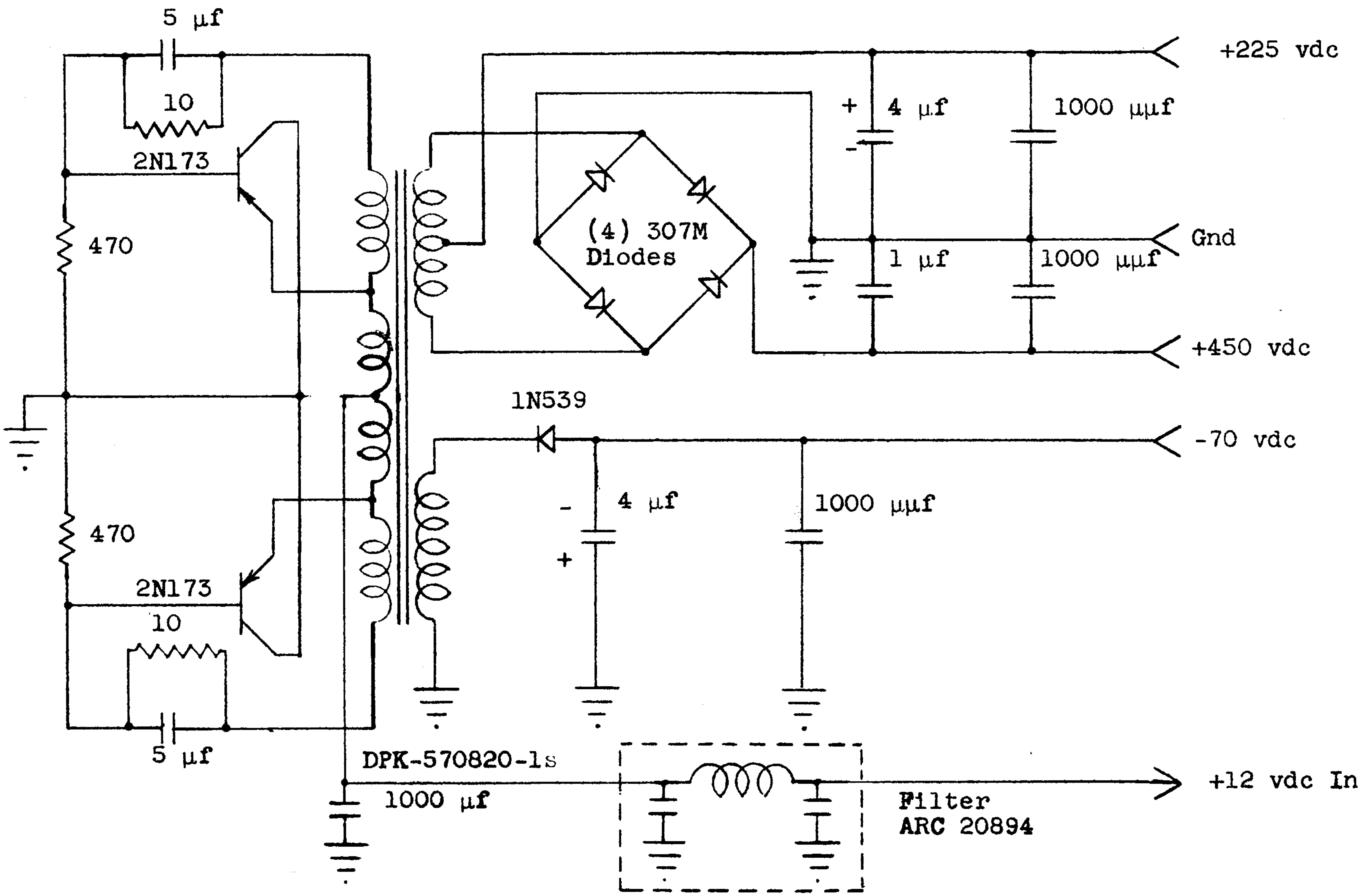


FIGURE 8-1

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DWN.

DWG. KHM-571120-1

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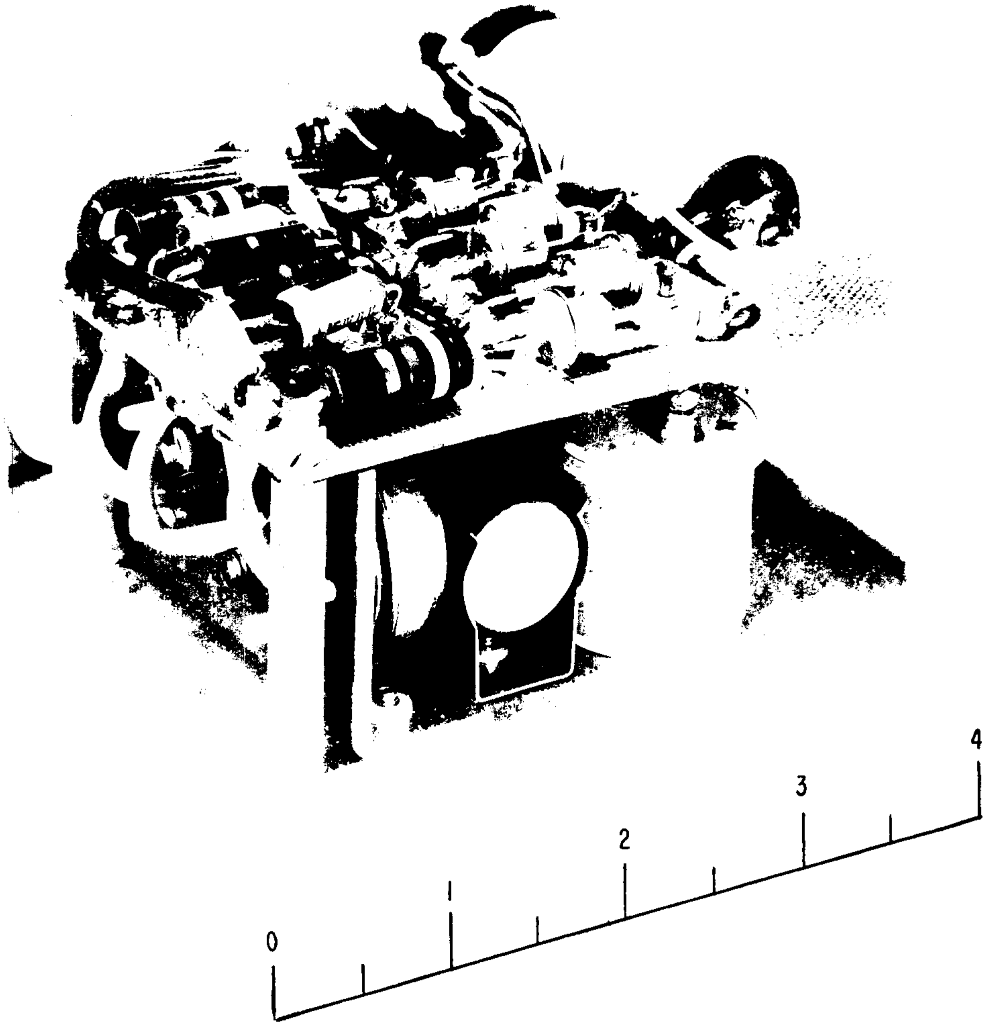


AT-3
DC POWER SUPPLY SUBASSEMBLY

FIGURE 8-2

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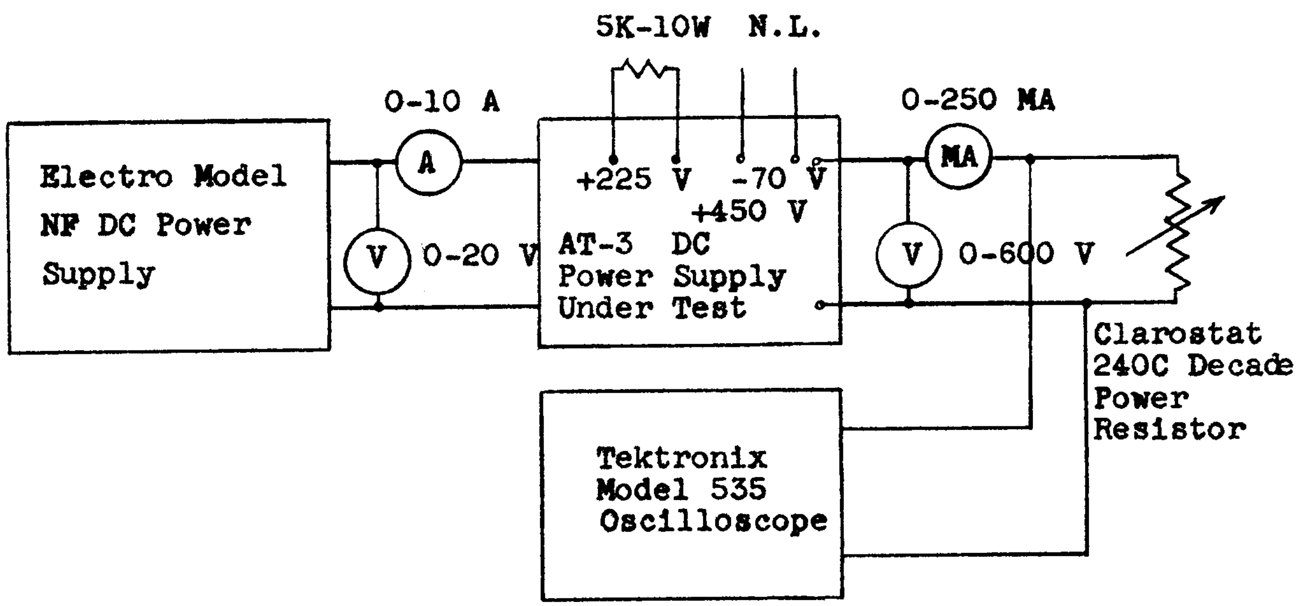
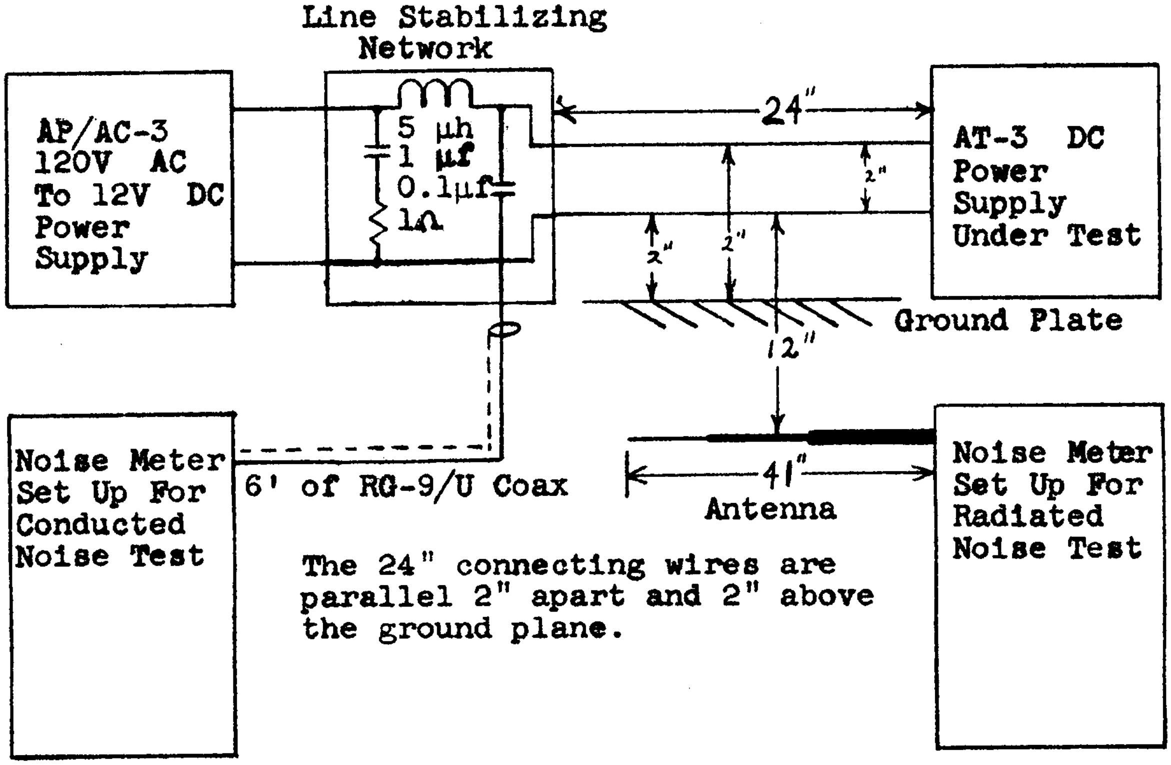
## LOAD AND RIPPLE CHARACTERISTICS




## CONDUCTED AND RADIATED NOISE CHARACTERISTICS




Noise Meter Used:

Ferris 35-A for 0.15 to 20 MC
Empire Devices NF 105 for 20 to 1000 MC

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| ISSUE | DATE | APP. | ISSUE | DATE | APP. | | AT-3 DC Power Supply Load & Noise Charact. Test Config. |
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FIGURE 8-3

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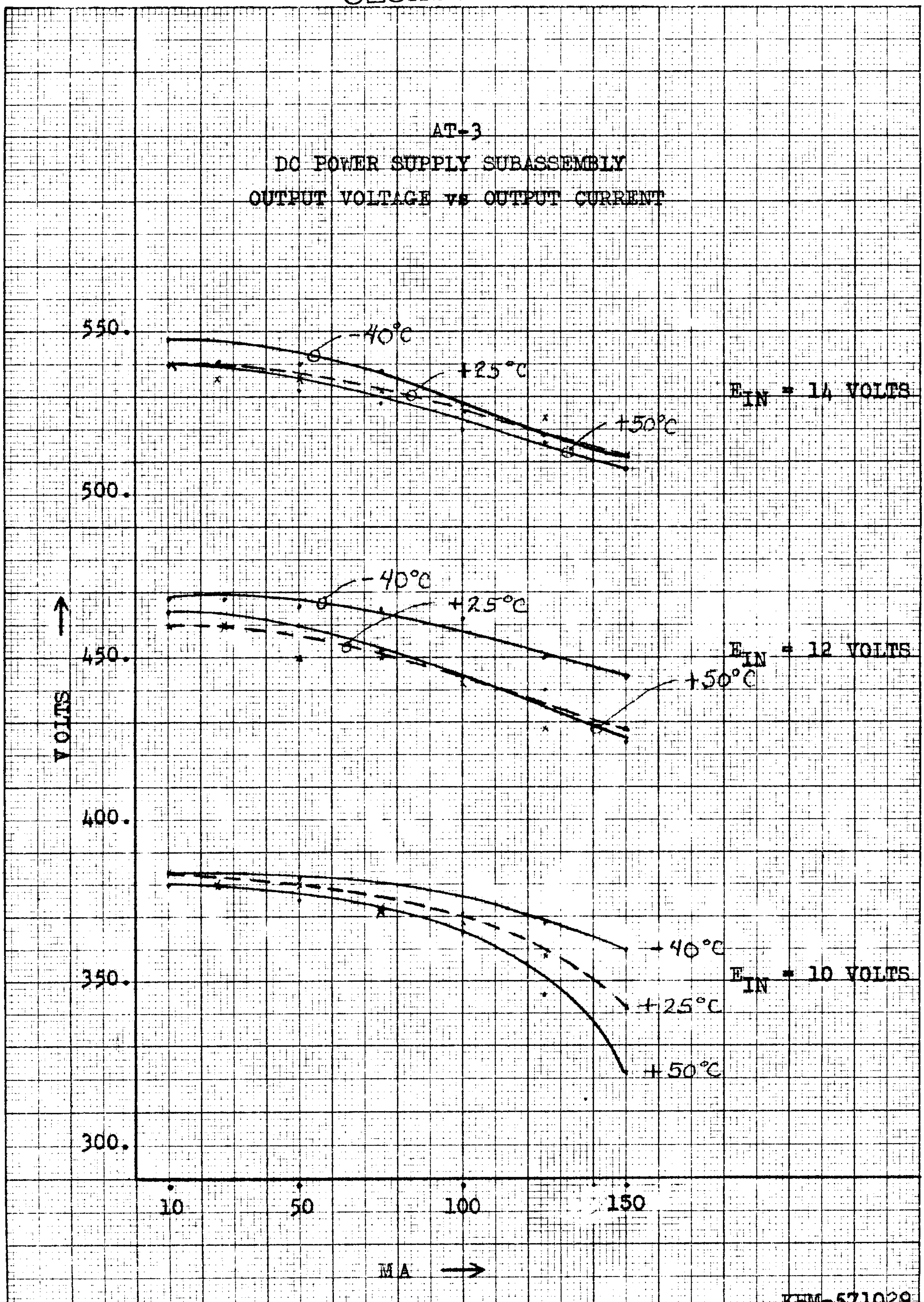

AT-3
DC POWER SUPPLY SUBASSEMBLY
OUTPUT VOLTAGE vs OUTPUT CURRENT
550
500
450
400
350
300
VOLTS
-40°C
+25°C
+50°C
$E_{IN}$ = 14 VOLTS
-40°C
+25°C
+50°C
$E_{IN}$ = 12 VOLTS
-40°C
+25°C
+50°C
$E_{IN}$ = 10 VOLTS
10
50
100
150
MA
KHM-571029


FIGURE 8-4

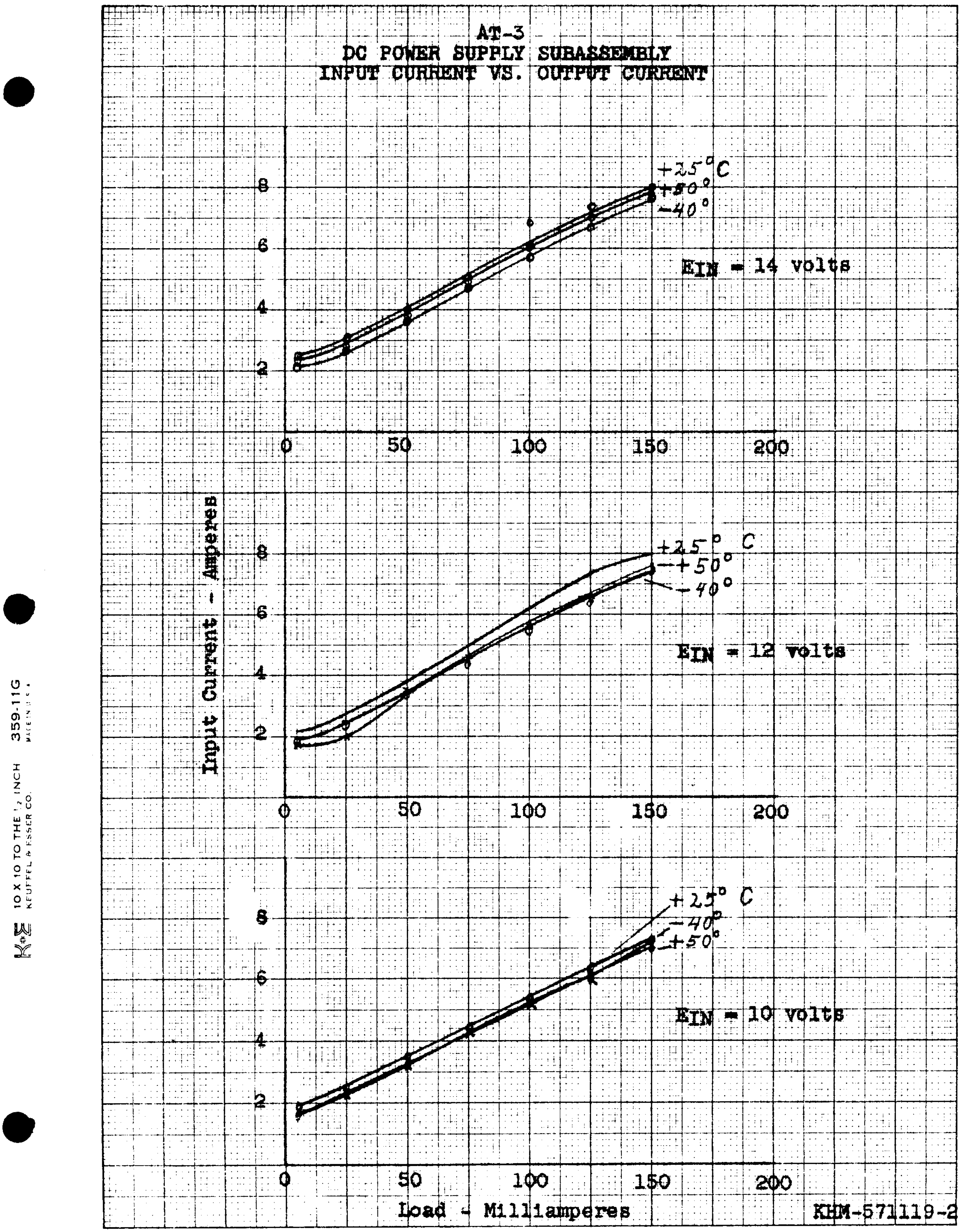
AT-3
DC POWER SUPPLY SUBASSEMBLY
INPUT CURRENT VS. OUTPUT CURRENT
+25° C
+50°
-40°
EIN = 14 volts
+25° C
+50°
-40°
EIN = 12 volts
+25° C
-40°
+50°
EIN = 10 volts
Input Current - Amperes
Load - Milliamperes
0
50
100
150
200
2
4
6
8
KHM-571119-2
10 X 10 TO THE 1/2 INCH
KEUFFEL & ESSER CO.
359-11G

FIGURE 8-5

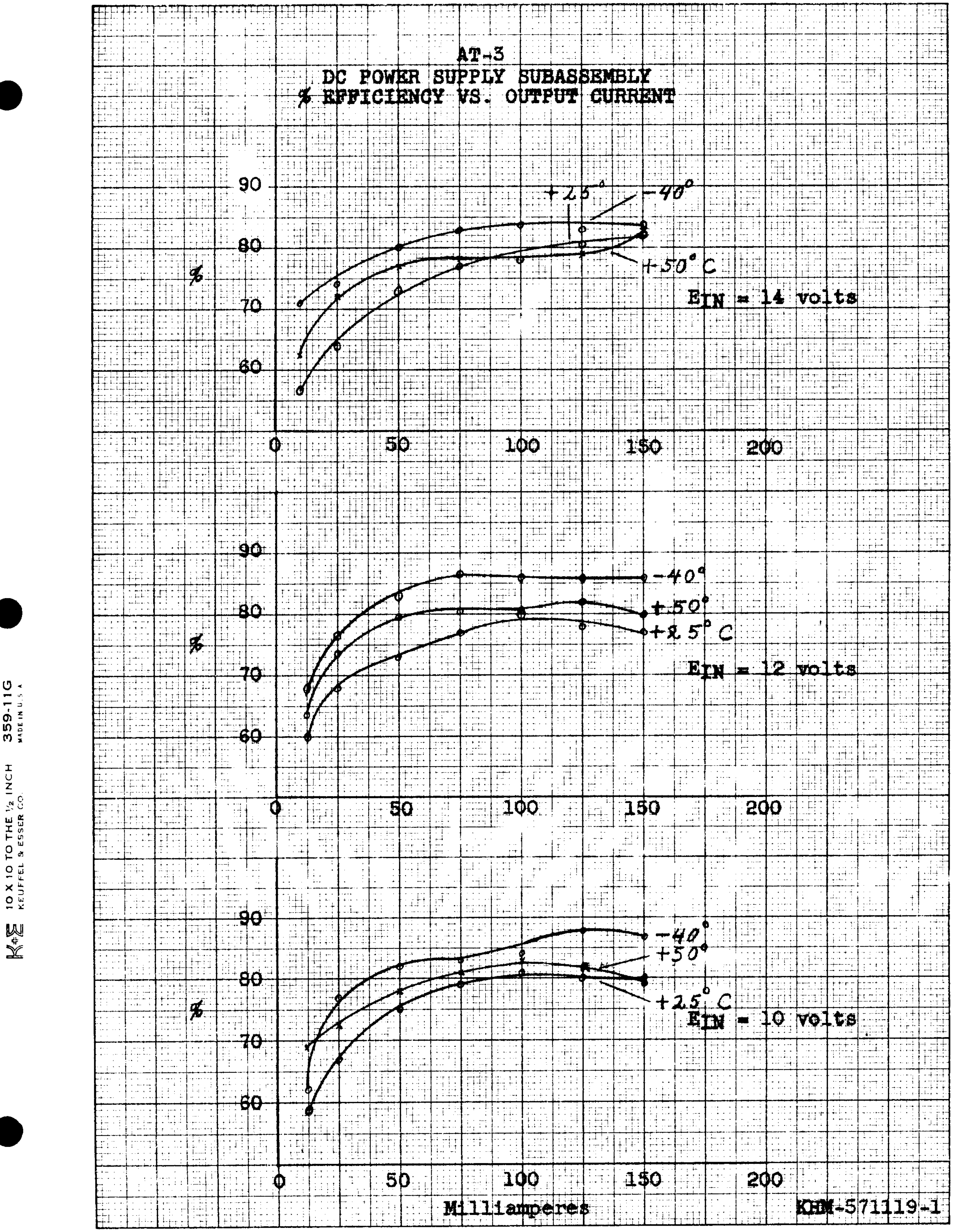
AT-3
DC POWER SUPPLY SUBASSEMBLY
% EFFICIENCY VS. OUTPUT CURRENT
90
80
70
60
%
+25°
-40°
+50° C
EIN = 14 volts
0
50
100
150
200
-40°
+50°
+25° C
EIN = 12 volts
-40°
+50°
+25° C
EIN = 10 volts
Milliamperes
KHM-571119-1
10 X 10 TO THE ½ INCH
KEUFFEL & ESSER CO.
359-11G
MADE IN U.S.A.

FIGURE 8-6

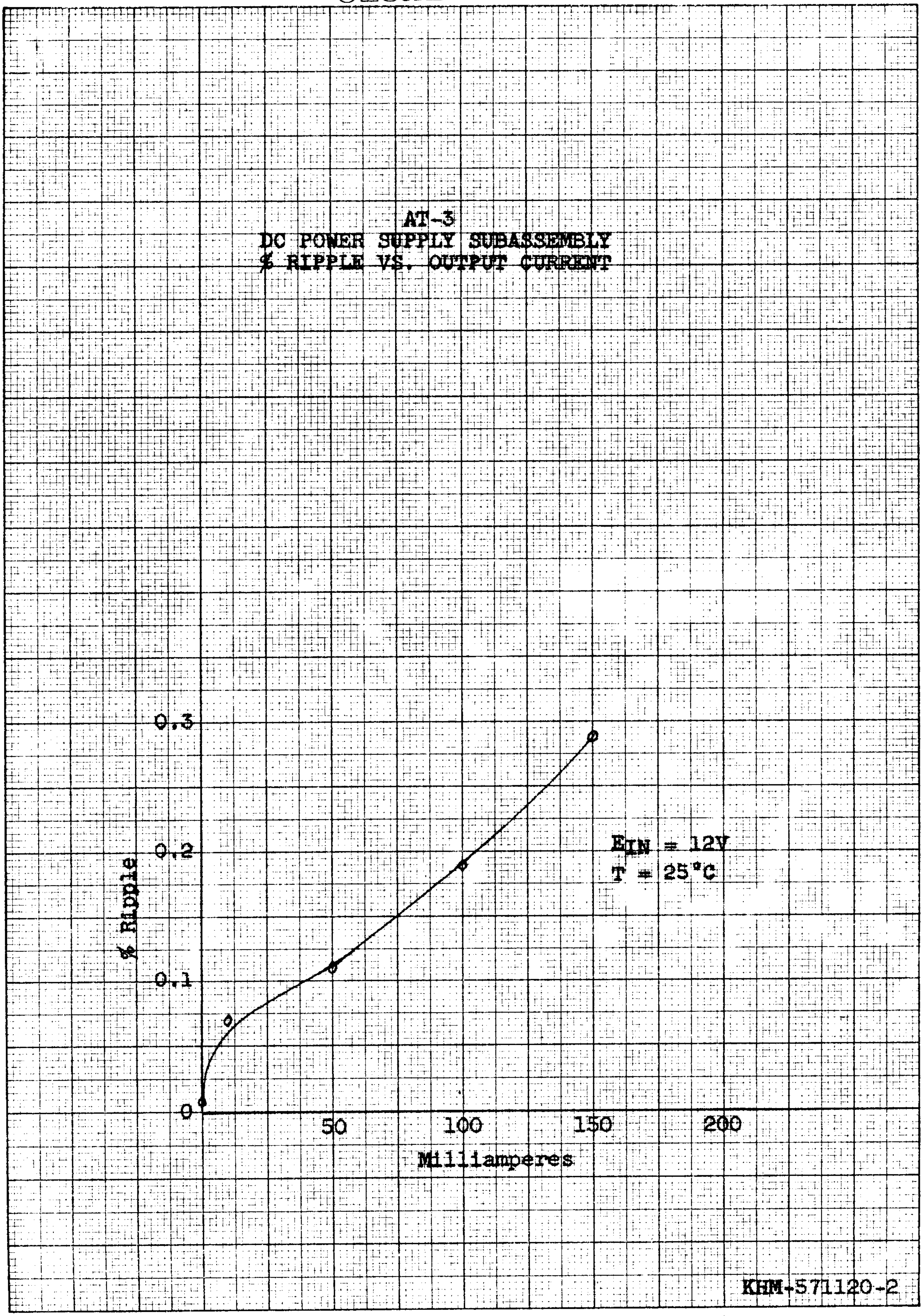
AT-3
DC POWER SUPPLY SUBASSEMBLY
% RIPPLE VS. OUTPUT CURRENT
% Ripple
0.3
0.2
0.1
0
50
100
150
200
Milliamperes
EIN = 12V
T = 25°C
KHM-571120-2
10 X 10 TO THE ½ INCH 359-11G
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 8-7

F. C. C. Sheet.
MADE IN U.S.A.

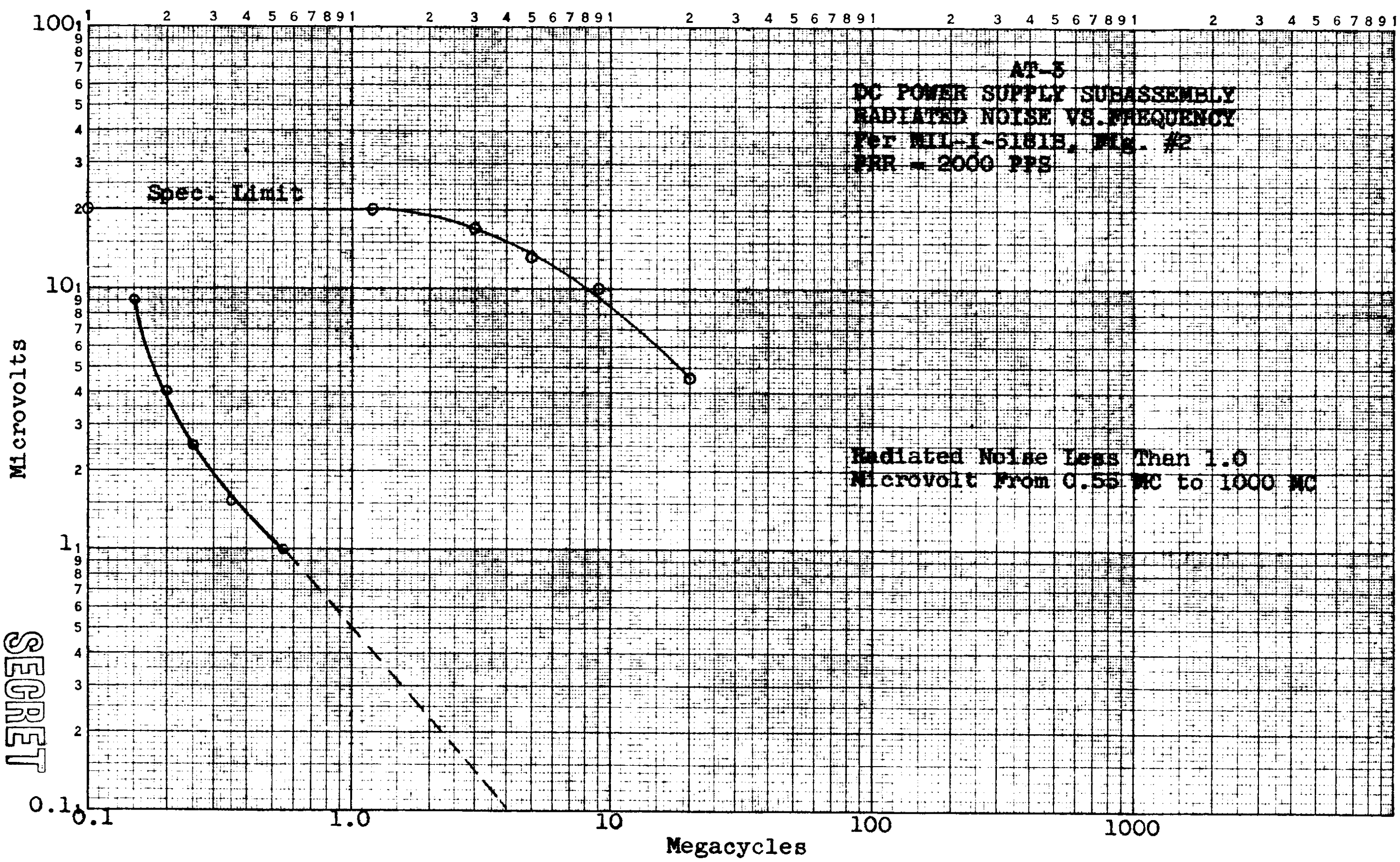


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**FIGURE** 8-8

**KHM**-571119-4

Logarithmic, 3 X 5 Cycles.
F. C. C. Sheet.
MADE IN U. S. A.

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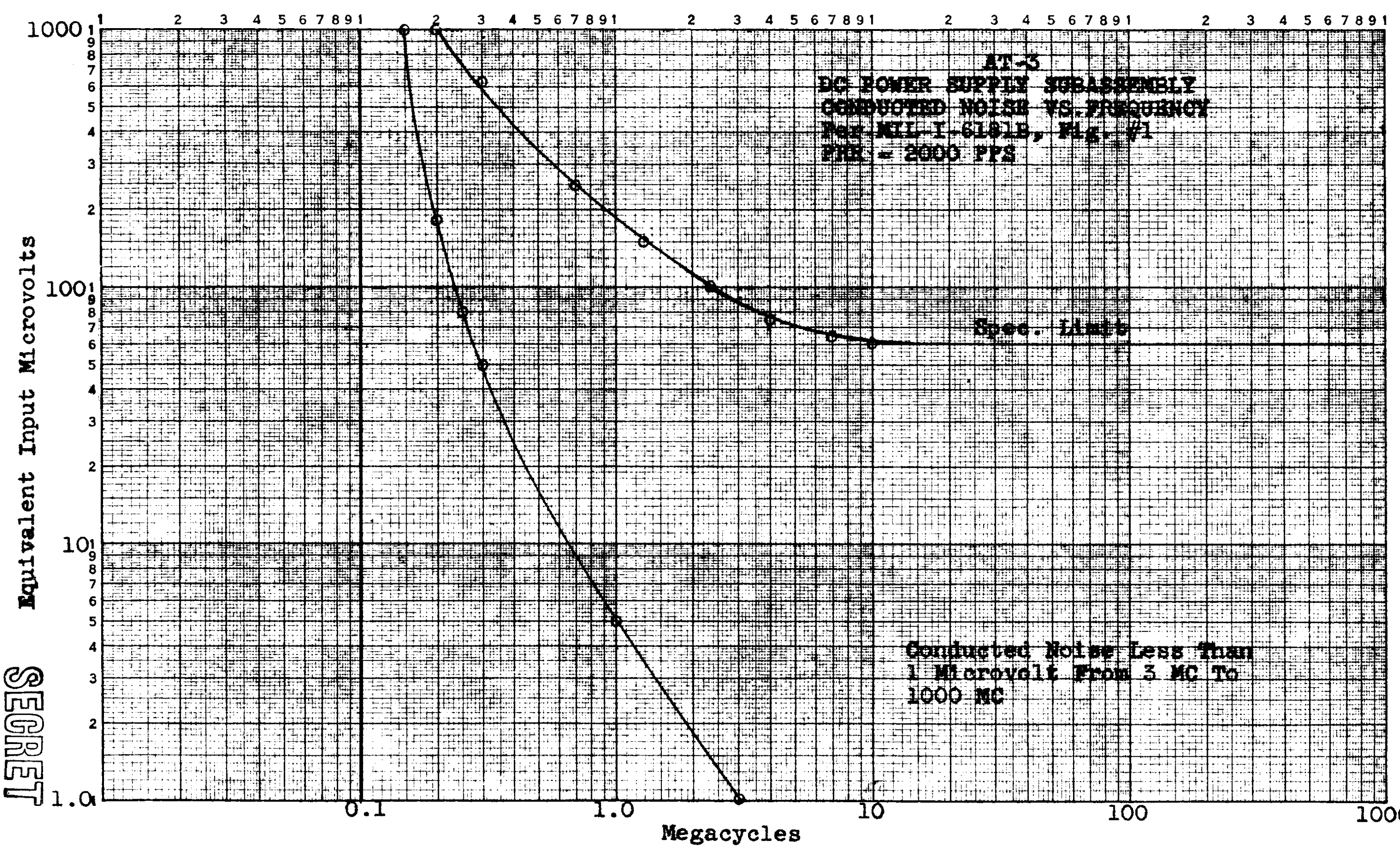


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**FIGURE** 8-9

KHM-571119-3

Conference Report
Radio Station AS-3
September 25, 1957

[redacted] 50X1
EA-122-1

## General

This report concerns a meeting held on 17 September 1957 at [redacted] The meeting was attended by: 50X1

[redacted] 50X1

The meeting reviewed the AS-3 program.

Discussion topics and conclusions are outlined below:

1. Request for receiver choice was again made, but no conclusion was indicated. During this and other conferences, [redacted] pointed out, the discussion favored the transistorized receiver. 50X1

   Acting on this information as the best available, [redacted] has proceeded with circuit design and packaging using the transistorized receiver as the system receiver choice. As there is a considerable difference between the power requirements of the vacuum tube receiver (much greater) versus the transistorized unit, any change in the power supply requirement from that of the transistorized receiver will result in a new power supply design and probable increase in volume of the AT-3. 50X1

2. A serious noise problem encountered during preliminary tests of the keyer motor with the keyer amplifier was discussed. Noise generated by the motor was sufficient to completely prevent normal keying by the tape. The availability of the motor used in the printer was to be investigated and made known to [redacted] 50X1

3. Delivery of the prototype system 60 days after completion and testing of a satisfactory bread-board model was established as a realizable goal.

4. It was decided to again incorporate the battery charge function of the AP/AC-3 (eliminated by Conference Report of 31 July), as this function is readily available.

Prepared by

RWH:sk

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